WARHOUSING FROZEN PORK BELLIES AND HAMS

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CONTENTS

	Page
Summary	1
Introduction	2
Procedure	2
Observations of warehousing operations—part 1 of study	2
Experiments conducted—part 2 of study	3
Experiment to determine weight loss during freezing and storage	3
Experiment to determine the amount of freezer burn loss during freezing and storage	4
Cost analysis—part 3 of study	4
Results of observations of warehousing operations—part 1 of study	5
Transportation of meat from packinghouse to warehouse	5
Warehouse receiving operations	5
Freezing and packaging methods before storage	6
Storage and refrigeration facilities	7
Handling loose meat for shipment	9
Results of experiments conducted—part 2 of study	10
Weight loss during freezing and storage	10
Total weight loss	10
Effect of freezing method	10
Effect of time in storage	12
Effect of packaging method	12
Effect of location on pallet	13
Freezer burn loss during freezing and storage	14
Effect of freezing method	14
Effect of time in storage	14
Effect of packaging method	14
Effect of location on pallet	15
Relationship between total weight loss and freezer burn	16
Results of cost analysis of systems for handling hams—part 3 of study	17
Conclusions and recommendations	18
Appendix	19

WAREHOUSING FROZEN PORK BELLIES AND HAMS

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SUMMARY

This study was initiated to gather information on the methods used to handle loose pork bellies and hams (loose meat) in seven refrigerated warehouses in six cities. Results of interviews with warehouse executives showed that a major problem confronting the industry is the lack of research data on the weight losses sustained by loose meat at various stages during marketing.

After industry practices had been determined, an experiment was conducted to compare the effects of three freezing methods, three packaging methods, and three storage periods on the weight loss of hams during handling through a refrigerated warehouse. Freezing methods compared were: A still-air freezer room, a forced-air freezer room, and a blast freezer. Packaging methods compared were: Glazed, glazed-polybagged, and unglazed-polybagged. Storage periods compared were for 2, 4, and 6 months. At the end of the 4- and 6-month storage periods, an experiment was conducted to determine the effect of the freezing and packaging methods used and time in storage on the amount of freezer burn forming on the surfaces of the hams.

Weight lost during initial freezing and the reabsorption of glaze and condensation moisture were the most important factors affecting the total weight loss sustained by hams. Hams frozen in the blast freezer lost less weight than those frozen in either the still-air or the forced-air freezer room. Reabsorption of glaze and condensation moisture during thawing restored a considerable amount of the weight lost during initial freezing. Nevertheless, the reabsorption ability of the hams decreased as storage time increased. There were no significant differences in the amount of total weight loss produced by any of the packaging methods tested. Hams stacked in the center of the pallet load, where they froze slowly, lost more weight than hams stacked on the corners of the top layers, where a faster freezing rate occurred.

The amount of freezer burn forming on the hams increased with time in storage. Hams receiving initial freezing in a forced-air freezer room developed significantly more freezer burn between the 4- and 6-month storage periods than those frozen in either a still-air freezer room or a blast freezer. Polybagging (enclosing pallet loads of loose meat in polyethylene bags) reduced the amount of freezer burn forming on the hams held in storage longer than 4 months. The more exposed the hams were to air surrounding the pallets, the more freezer burn they sustained. Under actual warehousing conditions, there was apparently no correlation between the amount of freezer burn forming on the surface of the hams and the amount of total weight loss.

Some warehousing services, such as blast freezing and glazing-polybagging, reduced weight losses and freezer burn losses. However, in some instances, the dollar value reduction in weight loss was not enough to offset the extra cost for the additional services.

Costs to the customer were compared for nine systems of handling hams through a refrigerated warehouse. Several handling systems were found to be low in cost, but the handling system selected should depend largely on the needs of the customer and on the basic services offered by the warehouse where the meat will be stored. The information developed in this report can be used as a guide in selecting a low-cost system applicable to the customer's particular situation.

INTRODUCTION

The practice of holding pork bellies and hams in frozen storage has become an important marketing tool by providing a means of balancing supply during periods of high and low swine production. During the peak month of May 1970, approximately 129.6 million pounds of frozen pork bellies and hams were stored in public refrigerated warehouses and meatpacking plants in 48 States.[1] Part of the meat held in frozen storage is traded on the commodity futures market. Frozen-pork-belly and skinned-ham futures are two of the more recent commodities traded on the Chicago Mercantile Exchange. Since frozen-pork-belly futures were first offered on the market, the number of contract units[2] traded has increased from 857 in 1961-62 to 2,287,292 in 1969-70.[3]

Several major problems adversely affect the efficiency of handling loose pork bellies and hams through refrigerated warehouses. One problem is that most loose meat is handled predominantly by manual labor. Other serious problems are the weight and freezer burn losses caused by moisture evaporation during freezing and storage. Very little research has been conducted to determine the amount of these losses to pork bellies and hams during freezing and storage, or to evaluate the effects of new packaging and handling methods on them. Without adequate knowledge of what losses can be expected, warehousemen have difficulty in determining their operating costs and pricing policies, which are two major factors that influence marketing decisions.

The purpose of this study was to find ways to improve the efficiency of marketing loose pork bellies and hams through determining what improvements were needed in the handling methods used for their transportation, freezing, and storage. This study was composed, essentially, of three parts. In part 1, observations were made of current transportation, freezing, and storage practices used by refrigerated warehouses in handling pork bellies and hams during freezing and storage. In part 2, experiments were conducted to determine and compare the amount of weight and freezer burn losses sustained by hams during freezing and storage. In part 3, cost analysis was made to compare the costs of nine handling systems consisting of various combinations of freezing and packaging methods and time in storage to assist customers of refrigerated warehouses in selecting the most economical system in handling their hams.

The procedures used in accomplishing each part are discussed individually in the report, followed by the findings of each part of the study.

PROCEDURE

Observations of Warehousing Operations—Part 1 of Study

Seven refrigerated warehouses were studied in six cities during the winter and spring of 1970 to identify current industry practices and problems involved in handling loose pork bellies and hams held in frozen storage. These six cities were in three of the nine regions in the United States in which the USDA's Statistical Reporting Service gathers information on warehouse holdings. As of 1970, these regions accounted for about 84 percent of the loose pork bellies and hams held in frozen storage by refrigerated warehouses. These regions comprise 16 of the eastern North Central, western North Central, and western South Central States.[4]

Personal interviews with warehouse executives and observations of warehousing operations and facilities were used to gather information about the following stages of distribution: (1) Transportation of meat from the packinghouse to the warehouse, (2) warehouse receiving operations, (3) freezing and packaging methods prior to storage, (4) storage and refrigeration facilities, and (5) handling loose meat for shipment to meatpacker or processor.

To determine the different conditions used for storing loose meat by the warehouses studied, measurements were taken of the air temperature, meat temperature, temperature differential over the

[1]United States Statistical Reporting Service. Summary of regional cold storage holdings. U.S. Dept. Agr., 22 pp. 1971.

[2]As of February 1971, a contract unit consists of 36,000 pounds of meat. Prior to that date, it consisted of 30,000 pounds.

[3]United States Commodity Exchange Authority. Commodity futures statistics, July 1969-June 1970, U.S. Dept. Agr., Statistical Bul. No. 464, 67 pp. 1971.

[4]See footnote 1.

coil, and the relative humidity at three to five locations in a total of eight freezer-storage rooms (two were in one warehouse). These rooms were used for both freezing and storing loose meat and other perishables.

Experiments Conducted—Part 2 of Study

Experiment to Determine Weight Loss During Freezing and Storage

Based on observations of industry practices, an experiment was designed to compare the effects of (1) three freezing methods (still-air, forced-air, and blast), (2) three packaging methods (glazed, glazed-polybagged, and unglazed-polybagged), and (3) three storage periods (2, 4, and 6 months) on the weight loss of hams during handling through one refrigerated warehouse. Twenty-seven pallet loads of fresh hams, weighing from 14 to 17 pounds each, were used for the experiment. Each of the 27 pallet loads received a different combination of freezing method, packaging method, and storage period (table 1). Weight-change data were subjected to analysis of variance, using a 3 x 3 x 3 factorial experimental design (appendix tables 12 to 15).

The hams came from hogs that were graded USDA Nos. 1, 2, and 3. The hogs were slaughtered at a meat packinghouse 2 days before the test was started. The carcasses were chilled overnight, broken into cuts, and trucked 60 miles in pallet-size, stainless steel tubs to the public warehouse that was used for the experiment.

Upon arrival at the warehouse, the hams were stacked on 40- by 48-inch wooden pallets for initial freezing. The temperatures of the hams, before freezing, ranged from 36° to 40° F. From the hams to be stacked on each pallet, 16 samples were selected at random and weighed to an accuracy of one-hundredth of a pound. Identification tags were attached to each to identify its initial freezing method, the packing treatment it would receive, and its location on the pallet. The sample hams were separated into four groups. They were then assigned a particular location on the pallet and stacked among the other hams so that they would be exposed to water spray treatments and to refrigerated air as follows: Location 1—no sides exposed (located internally in the stack); location 2—one side exposed (located between two other hams on any side of the stack on any layer except the top); location 3—two sides exposed (located at any corner of any layer in the stack except the top); location 4—three sides exposed (located at any corner of the top layer of the stack) (fig. 1).

As the hams were being stacked on each pallet, a wooden divider rack was placed between each layer of hams to allow proper air circulation for freezing, to stabilize the load, and to prevent the meat from freezing together into a solid mass. A thin polyethylene bag was slipped over each divider rack for sanitary purposes.

Table 1.–Experimental design for combination of freezing method, packaging method, and time in storage for 27 pallet loads of hams

Freezing method	Time in still-air storage	Packaging method: Glazed-polybagged = b_1 Pallet No.	Code	Unglazed-polybagged = b_2 Pallet No.	Code	Glazed only = b_3 Pallet No.	Code
Still-air = a_1	2 mo = c_1	1 =	$a_1b_1c_1$	4 =	$a_1b_2c_1$	7 =	$a_1b_3c_1$
	4 mo = c_2	2 =	$a_1b_1c_2$	5 =	$a_1b_2c_2$	8 =	$a_1b_3c_2$
	6 mo = c_3	3 =	$a_1b_1c_3$	6 =	$a_1b_2c_3$	9 =	$a_1b_3c_3$
Forced-air = a_2	2 mo = c_1	10 =	$a_2b_1c_1$	13 =	$a_2b_2c_1$	16 =	$a_2b_3c_1$
	4 mo = c_2	11 =	$a_2b_1c_2$	14 =	$a_2b_2c_2$	17 =	$a_2b_3c_2$
	6 mo = c_3	12 =	$a_2b_1c_3$	15 =	$a_2b_2c_3$	18 =	$a_2b_3c_3$
Blast-freeze = a_3	2 mo = c_1	19 =	$a_3b_1c_1$	22 =	$a_3b_2c_1$	25 =	$a_3b_3c_1$
	4 mo = c_2	20 =	$a_3b_1c_2$	23 =	$a_3b_2c_2$	26 =	$a_3b_3c_2$
	6 mo = c_3	21 =	$a_3b_1c_3$	24 =	$a_3b_2c_3$	27 =	$a_3b_3c_3$

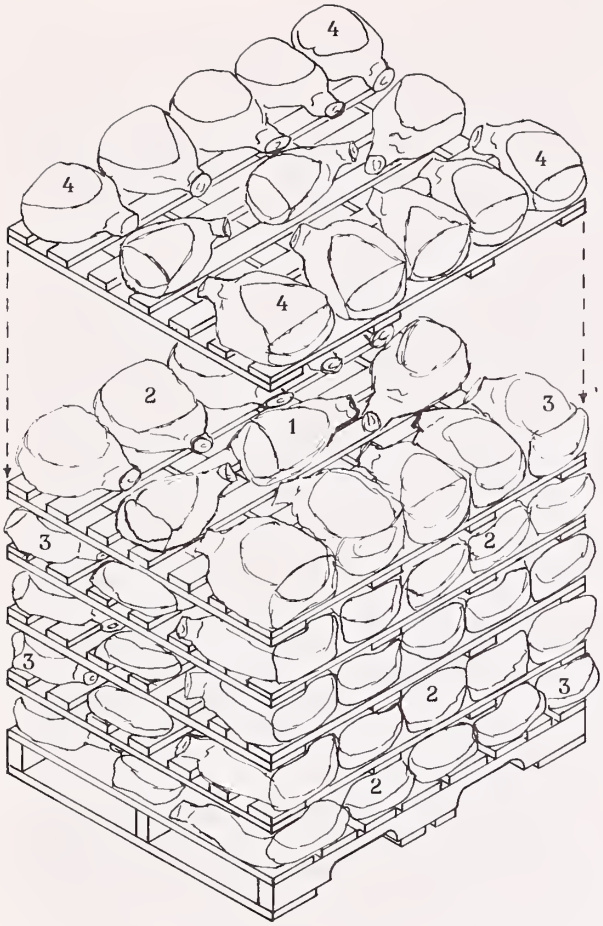

Figure 1.—Arrangement of hams on a pallet. Numbers denote location of sample hams in relation to exposure or lack of exposure to water spray treatments and to refrigerated air: (1) No sides exposed, (2) one side exposed, (3) two sides exposed, and (4) three sides exposed.

After being loaded with hams, the 27 test pallets were divided into three sets of nine pallet loads and subjected to initial freezing until the hams on the corners of the top layer reached 0° F. One set was frozen in a still-air freezer room for 5 days. One set was frozen in a forced-air freezer room for 3 days, and the remaining set was frozen in a blast freezer for 2 days.[5] After the initial freezing period, the sample hams were removed from the pallets and weighed to determine their weight change since the initial freezing. Then they were returned to their locations on the pallets.

The 27 pallet loads of hams then were divided again into three sets of nine each for packaging according to the predetermined experimental design (table 1). Each pallet load in one set was enclosed in a 2-mil-thick polyethylene bag (polybagged). Each pallet load in the second set was subjected to a fine mist of water spray for 5 minutes to glaze the hams on the perimeter of the pallet. After the glazing, each pallet load was polybagged. Each pallet load in the third set also was subjected to 5 minutes of water spray. These pallets were not polybagged, but were stored in the freezer room with only ice glaze for protection.

After being packaged, the 27 pallet loads of hams were again divided into three sets of nine each and placed in a still-air freezer room for storage tests. One set was stored for 2 months, one for 4 months, and one for 6 months. At the end of its respective storage period, each set was removed from storage; the hams were removed immediately from the pallets; and the sample hams were weighed to determine their weight change since glazing and storage. The sample hams were then thawed for approximately 20 hours at 60° F and reweighed. All the hams were then returned to the meat packinghouse for curing.

Experiment to Determine the Amount of Freezer Burn Loss During Freezing and Storage

Besides the amount of weight loss sustained by hams as the result of the packaging and freezing methods used and time in storage, the effect of these factors on the amount of freezer burn loss also was determined. At the end of the 4- and 6-month storage period, a USDA meat grader measured the number of square inches of freezer burn on the meaty surfaces of the sample hams with a clear acetate grid marked off in 1-inch squares. Since only a negligible amount of freezer burn was observed on hams that had been held in storage for 2 months, freezer burn was not measured for this period. Freezer burn data were subjected to analysis of variance, using a 3 x 3 x 2 factorial design (appendix table 16).

Cost Analysis—Part 3 of Study

The costs of the nine systems studied for warehousing hams were calculated by totaling the cost of the weight loss for each of the handling systems and the cost of warehousing services for each system. For the cost analyses, the handling systems consisted of the nine combinations of freezing and packaging methods and time in storage for the experiments with the pallet loads of hams. For purposes of the analyses, the weight losses sustained by hams during

[5]Ordinarily, the hams would freeze in a blast freezer in 1 day or less, but there was a mechanical breakdown in the blast freezer used for this test.

the 2-, 4-, and 6-month storage periods were averaged in order to reduce the variability within each system.

Some potential benefits that may be derived through the use of certain combinations of packaging and freezing methods (for example, reduced freezer burn loss or improved contamination protection) were not considered in the cost analyses, because these factors are very difficult to evaluate objectively.

RESULTS OF OBSERVATIONS OF WAREHOUSING OPERATIONS—PART 1 OF STUDY

The refrigerated warehouses observed ranged from newly constructed facilities to those that had been in operation for 50 years or more. Most older refrigerated warehouses were multilevel, rather than single level like the newer facilities. Therefore, a variety of methods was used to handle pork bellies and hams.

Transportation of Meat From Packinghouse to Warehouse

Fresh pork bellies and hams were shipped to the warehouse by both rail and truck, but truck was the predominant mode of transportation. Most meat was shipped from local meat packinghouses; however, some shipments came from as far away as 500 to 1,000 miles.

Most fresh meat cuts were shipped in bulk lots (fig. 2a) of 35,000 to 40,000 pounds. In some instances, they were shipped in fiber glass or metal tubs that hold about 2,000 pounds of meat each (fig. 2b). The tubs were used when the packinghouse and the warehouse were relatively close to one another, and the tubs could be returned easily to the packinghouse.

One warehouse observed was located adjacent to a packinghouse that transported its fresh, loose meat in fiber glass tubs which were then loaded onto dollies. The dollies were then towed with a tractor "train style" to the warehouse receiving dock. The fresh meat in some of the truck shipments observed was stacked on wooden pallets or in wire baskets. In others, each piece of meat was individually bagged in plastic or wrapped in kraft paper. Industry executives reported that an increasing number of meatpackers were shipping fresh, loose meat in polyethylene-lined fiberboard bins on pallets (fig. 3).

Figure 2.—(a), A bulk truckload of fresh pork bellies; (b) a fresh ham shipment in a metal tub.

Warehouse Receiving Operations

Loose meat was hand stacked on wooden pallets soon after it arrived at the warehouse. Wooden divider racks were placed between the layers of meat (fig. 4). Kraft paper or plastic sheets were placed on both sides of the divider racks as the meat was being stacked. These racks were used to allow proper air circulation for freezing, to stabilize the load, and to prevent the meat from freezing together into a solid mass.

Generally, two or three men were needed for 5 to 6 hours to unload and palletize a 35,000- to 40,000-pound load of meat. In addition, a forklift truck and driver were needed (on a part-time basis) to transport the meat to the freezer.

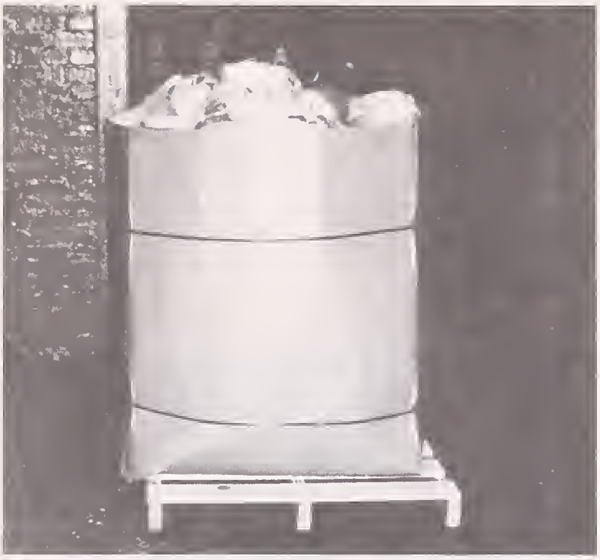

Figure 3.—A pallet-size, fiberboard bin on a pallet, loaded with fresh hams.

Figure 4.—A worker stacking pork bellies on a pallet as they are unloaded from a truck. Note wooden divider racks.

Unloading was faster when truckloads of loose meat were received in fiberboard bins on pallets or in fiber glass or metal tubs, rather than on the floor of the truck. It usually took one man with a forklift truck or pallet jack about one-half hour to unload the bins or tubs of meat from the truck. However, it was necessary for this meat to be removed from the bins or tubs and hand stacked on pallets prior to freezing. According to warehousemen, if the meat were left in the bins or tubs, it would be difficult to freeze it fast enough to prevent spoilage. In addition, the meat would freeze together, which would make it difficult to unload.

Freezing and Packaging Methods Before Storage

The temperature of bellies and hams generally ranged from 36° to 40° F before initial freezing. After the loose meat was palletized, it was frozen either in a still-air freezer room (fig. 5.); forced-air freezer room; or blast freezer. It generally took 5 to 7 days to freeze the meat to 0° F in a still-air freezer room; 3 to 4 days in a forced-air freezer room; and 12 to 24 hours in a blast freezer.

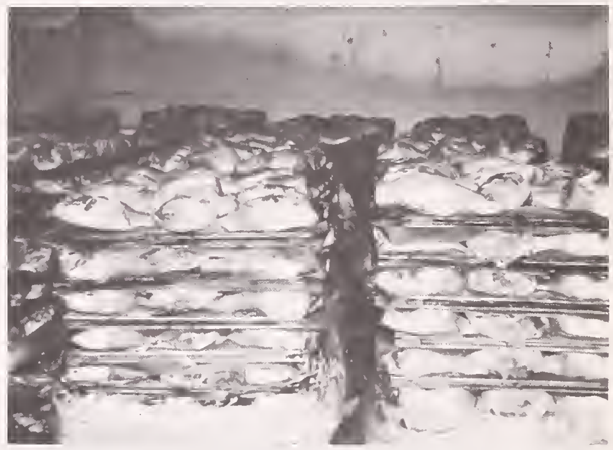

Figure 5.—Pallet loads of fresh hams being frozen in a still-air freezer room.

Several packaging methods were used to protect the frozen meat during storage. One of these methods, glazing, was accomplished either by dipping each piece of meat in water or by spraying water for 3 to 5 minutes on the perimeter of the pallet load of meat (fig. 6). The water freezes as a result of

Figure 6.—A pallet load of frozen pork bellies being sprayed with water to form an ice glaze.

contact with the frozen meat, thereby forming a thin coating of ice glaze. Glazing was the traditional method used by industry to protect meat from excessive weight loss and freezer burn. The meat usually was glazed only once, prior to storage, but sometimes it was reglazed when storage was prolonged beyond 4 to 6 months.

A relatively new method for protecting the meat during frozen storage consisted of placing a polyethylene bag around the whole pallet load. This method is known as "polybagging." The procedures used for placing the polyethylene bag around the pallet loads varied among the warehouses studied. In some warehouses, the polyethylene bag was placed on the pallet and rolled down like a stocking before the meat was hand stacked on the pallet. Then, the loaded pallet, with its polyethylene bag still rolled down, was placed in a freezer-storage room. After freezing, the meat was glazed with water, and the polyethylene bag was rolled up around the meat. In some warehouses, polybagging was accomplished by stacking the meat on a wooden box rack that could be lifted off the pallet with a forklift.

After the pallet load of meat had been frozen and glazed, the box rack with its load of meat (called racked meat) was lifted above the pallet with a forklift so that a polyethylene bag could be placed between the two. The racked meat was then redeposited on the pallet, the bag on the pallet rolled up over the racked meat, the air inside the bag removed with an industrial vacuum, and the bag tied closed with string (fig. 7). Several refrigerated warehouses did not seal the bags; they only folded them over at the top. In another warehouse, polyethylene bags were slipped over the pallet loads from the top after the meat had been frozen and glazed (fig. 8). In another, polyethylene bags were slipped over the pallet loads of meat before freezing, and the meat was blast frozen and stored without glazing.

Figure 7.—Polybagging a pallet load of frozen and glazed pork bellies: (a), Racked meat is lifted off the pallet with a forklift so that a polyethylene bag can be positioned on the pallet; (b), workers pull the polyethylene bag up around the meat, evacuate the air from the bag, and tie the bag closed with string.

Figure 8.—Workers slip polyethylene bags over pallet loads of racked pork bellies.

Storage and Refrigeration Facilities

Loose, frozen meat in the warehouses studied was stored at temperatures that ranged from 0° to -15° F. The storage time depended largely upon the demand on the meatpacker or processor, but usually varied from several weeks to 6 months. In most instances, the meat was left on the pallet during storage. However, the storage methods varied among the warehouses studied (fig. 9). In some of the older warehouses, the loaded pallets were stacked only two levels high (a); whereas, in some of the newer ware-

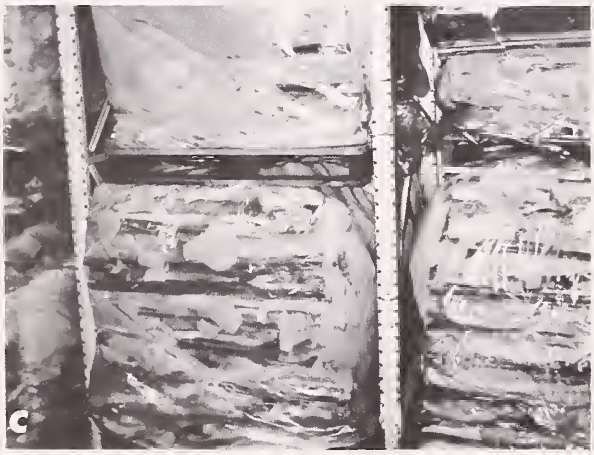

Figure 9.—Various methods used to store loose, frozen meat: (a), Glazed, open pallets, stacked two levels high; (b), pallets stacked up to four levels high; (c), polybagged pallets stacked on metal racks; (d), meat removed from pallets and stacked in large bins, the fronts of which are covered with polyethylene film.

houses, they were stacked up to four levels high (b). In some, the pallets of meat were stacked on metal racks (c). In two others, the meat was removed from the pallets and stacked in large bins, the fronts of which were then covered with a polyethylene film (d).

Environmental conditions and refrigeration facilities were observed in eight freezer-storage rooms. Five had still-air refrigeration, and three had forced-air refrigeration. The range and average of product and air temperatures, and temperature differentials over the coil in these rooms, are shown in table 2.

Table 2.–Range and average of product and air temperatures, and temperature differentials over the coil in eight rooms used for freezing and storing pork bellies and hams

Temperature	Range	Average
	° *F*	° *F*
Product	-15 to +12	-0.2
Air (at product)	-15 to 0	-5.9
Differential over coil	+1.6 to +8.7	+5.5

The measured product temperatures varied widely in the freezer-storage rooms, ranging from -15° to +12° F, because some meat had just been brought into the rooms for freezing, whereas other meat was in the process of being frozen or already frozen and being stored until removed for shipment from the warehouse.

The air temperatures at the product (within 12 inches) varied as much as 15° (table 2). This variance, also, can be explained by the mixed product temperatures in the warehouse freezer-storage rooms.

The greatest temperature differential over the coil occurred in the forced-air freezer rooms. The coil in these rooms had a relatively small surface area, and a small coil surface area requires a greater temperature differential over the coil in order to refrigerate. The temperature differential over the coil in one newly constructed warehouse equipped with circular, ceiling-mounted, forced-air coils was not obtained, because these coils were inaccessible (fig. 10).

Relative humidity (RH) ranged from 43.5 to 84.5 percent in the warehouse freezer storage rooms studied. RH readings were highest in the forced-air freezer rooms, with one exception. This occurred in the newly constructed warehouse with the circular, ceiling-mounted, forced-air coils. The relative humidity in this warehouse was lower than that found

Figure 10.—A circular, ceiling-mounted, forced-air coil.

in the forced-air freezer rooms in other warehouses and in some of the still-air freezer rooms.

Air velocities over the product in the still-air freezer rooms were negligible. In rooms with forced air, the air velocity ranged from about 35 to 100 feet per minute (ft/min), depending on location in relation to the fan. Air velocity over the product was recorded in only one blast freezer, where it averaged about 200 ft/min.

Handling Loose Meat for Shipment

Several methods were used by refrigerated warehousemen in handling loose meat for shipment to the meatpacker or processor. At the end of the storage period, the pallet loads of loose meat usually were removed from storage and brought by forklift truck to the loading dock. Each piece of meat was removed manually from the pallets and stacked or thrown into a truck for shipment back to the meatpacker or processor. The walls of the truck usually were lined with kraft paper, and wood racks were placed on the floor to allow air circulation around the load. In some warehouses, the loose meat was removed manually from the pallets and thrown into pallet-size, fiber

glass or metal tubs, fiberboard bins, or wire baskets which were then loaded into the trucks with pallet jacks or forklifts. In some local shipments, the loose meat was left on the pallets and loaded directly into trucks.

Most meat was transported to meatpackers or processors at 0° F. However, when partial thawing during transit was desired by a meatpacker or processor, the truck thermostats were set according to the receiving firm's specifications.

RESULTS OF EXPERIMENTS CONDUCTED—PART 2 OF STUDY

Weight Loss During Freezing and Storage

Total Weight Loss

For the purposes of this report, the total weight loss to hams was the net loss from the time that they were received fresh at the warehouse dock until after they were returned to the meatpacker (or shipped to a processor) and thawed for curing (table 3). The total weight loss was the cumulative result of the reduction in weight during initial freezing and the subsequent reabsorption of moisture during glazing, storage, and in some instances, thawing. The weight changes that contributed to the chronological development of total weight loss were:

(1) Weight change from initial freezing: The weight change of hams was greatest during initial freezing. This change was always a reduction in weight, with the loss averaging 1.03 percent for all freezing methods.

(2) Weight change from glazing and storage: Following their reduction in weight as a result of initial freezing, all the hams—regardless of the packaging method used—showed weight increases during storage. These increases were expected for meat that had been spray-glazed before storage. However, all the unglazed hams also registered weight increases during storage. Storage weight increases not explained by glazing were attributed mainly to frozen moisture condensation which accumulated on the hams while they were being held in unrefrigerated rooms prior to bagging and weighing.

(3) Weight change at end of warehousing: The weight change at the end of warehousing was the net amount of weight change that had occurred to hams from the time that they were received fresh at the warehouse dock until they were returned to the dock, ready for loading for shipment to the meatpacker or processor. This weight change was sustained by hams during their dock-to-dock handling, while they were under the responsibility of the public warehouse.

(4) Weight change from thawing: While thawing, the hams showed a spongelike capability for absorbing glaze and condensation moisture. This absorption weight gain was important in offsetting weight losses incurred during initial freezing. However, the amount of thaw reabsorption decreased significantly as storage time increased (appendix table 14). Apparently, as time in storage increased, the reabsorption capability of the hams steadily decreased. For all the freezing and packaging methods used, hams that were thawed after 2 months' storage absorbed all the glaze and condensation moisture that remained on the surface of the hams at the termination of storage (0.33 percent), plus an additional 0.25-percent condensation moisture that had accumulated during thawing. This provided a net reabsorption weight gain of 0.58 percent (0.33 + 0.25—see table 3). At the end of 4 months, however, there was a 0.39-percent weight loss during thaw that offset the 0.60-percent glazing and storage weight gain, leaving only 0.21 percent net reabsorption weight gain (0.60 - 0.39). After 6 months' storage, there was a 0.63-percent thaw weight loss, compared with a 0.53-percent glazing and storage weight gain, leaving a 0.10 percent net reabsorption weight loss (0.53 - 0.63).

Effect of Freezing Method

During initial freezing, the amount of weight loss sustained by meat frozen by the three different methods was highly significant. The weight loss sustained by hams frozen in the blast freezer was 0.79 percent, as compared with 1.09 percent for those frozen in a forced-air room, and 1.22 percent for those frozen in a still-air room. The amount of weight loss was related directly to the freezing rate—the faster freezing occurred, the less weight lost.

The strong influence of the initial freezing method on weight loss extended throughout the experiment and resulted in significant differences in the amount of total weight loss sustained by the meat (appendix table 15). Hams subjected to initial freezing in the

Table 3.–Development of total weight loss of 27 pallet loads of hams as they moved through a refrigerated warehouse, by time in storage and freezing and packaging methods

Time in storage and freezing and packaging method	Weight change from initial freezing	Weight change from glazing and storage		Weight change at end of warehousing	Weight change from thawing		Total weight loss
	Percent	*Percent*		*Percent*	*Percent*		*Percent*
2 months							
Still-air:							
Glazed, polybagged	-1.23	+0.51	=	-0.72	+0.34	=	0.38
Unglazed, polybagged	-1.14	+.32	=	-.82	+.25	=	.57
Glazed only	-1.28	+.39	=	-.89	+.39	=	.50
Forced-air:							
Glazed, polybagged	-1.07	+.56	=	-.51	+.04	=	.47
Unglazed, polybagged	-1.10	+.01	=	-1.09	+.33	=	.76
Glazed only	-1.15	+.32	=	-.83	+.44	=	.39
Blast freeze:							
Glazed, polybagged	-.91	+.43	=	-.48	+.06	=	.42
Unglazed, polybagged	-.84	+.28	=	-.56	+.21	=	.35
Glazed only	-.76	+.14	=	-.62	+.18	=	.44
Average	-1.05	+.33	=	-.72	+.25	=	.47
4 months							
Still-air:							
Glazed, polybagged	-1.15	+.81	=	-.34	-.36	=	.70
Unglazed, polybagged	-1.16	+.30	=	-.86	-.27	=	1.13
Glazed only	-1.18	+.60	=	-.58	-.58	=	1.16
Forced-air:							
Glazed, polybagged	-1.24	+.50	=	-.74	-.58	=	1.32
Unglazed, polybagged	-1.29	+.36	=	-.93	-.06	=	.99
Glazed only	-.97	+.83	=	-.14	-.56	=	.70
Blast freeze:							
Glazed, polybagged	-.77	+.76	=	-.01	-.56	=	.57
Unglazed, polybagged	-.97	+.53	=	-.44	-.37	=	.81
Glazed only	-.59	+.67	=	+.08	-.19	=	.11
Average	-1.04	+.60	=	-.44	-.39	=	.83
6 months							
Still-air:							
Glazed, polybagged	-1.14	+.65	=	-.49	-.57	=	1.06
Unglazed, polybagged	-1.26	+.33	=	-.93	-.28	=	1.21
Glazed only	-1.38	+.53	=	-.85	-.75	=	1.60
Forced-air:							
Glazed, polybagged	-.99	+.63	=	-.36	-.69	=	1.05
Unglazed, polybagged	-1.15	+.42	=	-.73	-.60	=	1.33
Glazed only	-.88	+.41	=	-.47	-.67	=	1.14
Blast freeze:							
Glazed, polybagged	-.96	+.68	=	-.28	-.39	=	.67
Unglazed, polybagged	-.51	+.39	=	-.12	-.57	=	.69
Glazed only	-.78	+.72	=	-.06	-1.12	=	1.18
Average	-1.00	+.53	=	-.47	-.63	=	1.10

blast freezer averaged less weight loss at the end of storage and less total weight loss than those frozen in either the forced-air or still-air rooms (tables 4 and 5).

Effect of Time in Storage

Weight gains by hams during glazing and storage partly offset weight losses sustained during initial freezing. As a result, hams averaged a weight loss, for all the freezing and packaging methods, of 0.72 percent after 2 months' storage, 0.44 percent after 4 months' storage, and 0.47 percent after 6 months' storage (table 3). Apparently, the weight changes at this point are influenced more by glazing and storage weight gains than by time in storage. Weight change at the end of warehousing varied inversely with the glazing and storage weight change.

The total weight loss of the thawed hams increased significantly as time in storage increased (appendix table 15). Regardless of the freezing and packaging methods used, hams that had been stored for 2 months averaged a total weight loss after thawing of 0.47 percent; those that had been stored for 4 months averaged 0.83 percent; and those that had been stored for 6 months averaged 1.10 percent (table 3). However, this increasing weight loss appeared to be caused more by the decreasing absorption capability of the meat than by moisture evaporation during storage, since all the meat showed weight gains during storage.

Effect of Packaging Method

The weight loss of hams when removed from storage at the end of 2, 4, and 6 months, respectively, averaged 0.44 percent for those that had been glazed and polybagged, 0.72 percent for those that had been polybagged only; and 0.48 percent for those that had been glazed only (table 4). A difference in weight loss of only 0.04 percent was found between hams that had been glazed and polybagged (0.44 percent) and those that had been glazed only (0.48 percent). However, hams that had been polybagged only and not

Table 4.—The effects of freezing method, time in storage, and packaging method on the weight change at end of storage and before thawing for 27 pallet loads of hams[1]

Freezing method	Time in still-air storage	Packaging method			Average
		Glazed-polybagged, percentage of weight change	Unglazed-polybagged, percentage of weight change	Glazed only, percentage of weight change	
	Months	*Percent*	*Percent*	*Percent*	
Still-air	2	-0.72	-0.82	-0.89	
	4	-.34	-.86	-.58	
	6	-.49	-.93	-.85	
Average		-.52	-.87	-.77	-0.72
Forced-air	2	-.51	-1.09	-.83	
	4	-.74	-.93	-.14	
	6	-.36	-.73	-.47	
Average		-.54	-.92	-.48	-.65
Blast freezer	2	-.48	-.56	-.62	
	4	-.01	-.44	+.08	
	6	-.28	-.12	-.06	
Average		-.26	-.37	-.20	-.28
Average		-.44	-.72	-.48	

[1] Each value represents the average weight change of 16 sample hams on one pallet.

Table 5.—The effect of freezing method, packaging method, and time in storage on total weight change after thawing for 27 pallet loads of hams[1]

Freezing method	Time in still-air storage	Packaging method			Average
		Glazed-polybagged, percentage of weight change	Unglazed-polybagged, percentage of weight change	Glazed only, percentage of weight change	
	Months	*Percent*	*Percent*	*Percent*	
Still-air	2	-0.38	-0.57	-0.50	
	4	-.70	-1.13	-1.16	
	6	-1.06	-1.21	-1.60	
Average		-.71	-.97	-1.09	-0.92
Forced-air	2	-.47	-.76	-.39	
	4	-1.32	-.99	-.70	
	6	-1.05	-1.33	-1.14	
Average		-.95	-1.03	-.74	-.91
Blast freezer	2	-.42	-.35	-.44	
	4	-.57	-.81	-.11	
	6	-.67	-.69	-1.18	
Average		-.55	-.62	-.58	-.58
Average		-.74	-.87	-.80	

[1] Each value represents the average weight change of 16 sample hams on one pallet.

glazed (0.72 percent) lost 0.28 percent more weight than did hams that were both glazed and polybagged (0.44 percent). The low weight loss for glazed meat at the end of storage was attributable largely to the ice remaining on the hams.

After thawing and reabsorption, no significant differences were found in the total weight loss between hams packaged by any of the three methods (appendix table 15). The total weight loss for hams that had been glazed and polybagged averaged 0.74 percent, as compared with 0.87 percent for those that had been polybagged only, and 0.80 percent for those that had been glazed only (table 5).

Effect of Location on Pallet

Highly significant differences occurred in the amount of weight changes for hams stacked at different locations on the pallets (appendix tables 12 to 15). Table 6 shows the effect of pallet location on the weight changes of hams during freezing, glazing and storage, and thawing.

During initial freezing, the weight loss of hams placed internally in the pallet load with no sides exposed (location 1) was 1.16 percent. Those between two other hams on any side of the stack on any internal layer with one side exposed (location 2) lost 1.03 percent; those at any corner of any internal layer with two sides exposed (location 3) lost 0.99 percent; and those at any corner of the top layer with three sides exposed (location 4) lost 0.95 percent. Hams with the most exposure froze the fastest and shrank the least.

During glazing and storage, the hams increased in weight proportionately to their exposure to water spray treatments and to refrigerated air as a result of their location in the pallet load. Hams that received the greatest exposure on the outside of the pallet load increased in weight the most, because they had accumulated the most ice during glazing.

During thawing, the direct opposite occurred. Hams stacked in the more exposed positions (location 4) lost more weight than those in less exposed positions (locations 1, 2, and 3). The reason

Table 6.–Effect of location on pallet on weight changes of hams during freezing, storage, and thawing[1]

Location on pallet[2]	Sides exposed	Weight change from initial freezing	Weight change from glazing and storage	Weight change from thawing	Total weight loss
	Number	*Percent*	*Percent*	*Percent*	*Percent*
1	0	-1.16	+0.27	-0.23	1.12
2	1	-1.03	+.34	-.22	.91
3	2	-.99	+.47	-.25	.77
4	3	-.95	+.86	-.32	.41

[1] Each value is the average of the changes in 108 sample hams.

[2] See figure 1 for illustration of locations on the pallet.

for this difference was not apparent. Hams in the more exposed positions may have had most of their moisture reabsorption capacity satisfied during glazing, and as a result, were less receptive to further reabsorption during thawing.

Hams that received the greatest exposure had the lowest total weight loss. Those with three sides exposed (location 4) sustained a total weight loss of 0.41 percent, as compared with 1.12 percent for those with no sides exposed (location 1). These results confirmed the previous findings, which exemplify the strong influence of the initial freezing rate on the amount of total weight lost by hams.

Freezer Burn Loss During Freezing and Storage

When ice crystals evaporate on the surface of frozen meat, a number of air pockets form between the meat fibers. These air pockets cause the development of patches of discolored tissue, which the meat industry refers to as "freezer burn." If an excessive amount of freezer burn develops during storage, the meat must be trimmed. This trimming causes additional losses that are attributable to freezing and storage treatments.

The amount of freezer burn developing on the hams as a result of freezing method, time in storage, and packaging method is shown in table 7. Even at the end of 6 months of storage, none of the hams in the experiment were burned severely enough or deeply enough to warrant trimming before processing, or to disqualify them from trading on the Chicago Mercantile Exchange.[6]

[6]Chicago Mercantile Exchange. Facts you should know about the Chicago Mercantile Exchange and its commodities. 29 pp., Chicago. 1969.

Effect of Freezing Method

Of the three initial freezing methods tested, the forced-air freezing method caused the greatest amount of freezer burn to form on the hams stored between 4 and 6 months. This is indicated by the significant interaction between freezing methods and time in storage (appendix table 16). At the end of the 4-month storage period, the difference in the amount of freezer burn on all hams was about the same (table 8). However, at the end of 6 months, the amount of freezer burn had tripled on hams frozen by the forced-air freezing method, whereas it had only doubled on hams frozen by the other two methods.

Effect of Time in Storage

The average number of square inches of freezer burn on hams more than doubled between the 4- and 6-month storage periods. Significant interactions between freezing method and time in storage and between packaging method and time in storage conceal the causes of differences in amounts of freezer burn sustained by hams between storage periods (appendix table 16). The effects of these interactions are discussed in the preceding and following sections.

Effect of Packaging Method

The effect of the significant interaction between packaging method and time in storage on the amount of freezer burn on hams is shown in table 9. Between the 4- and 6-month storage periods, the amount of freezer burn more than tripled on hams that were glazed only and stored on open pallets, whereas the amount of freezer burn doubled only on the hams protected with polybags.

Table 7.–The effect of freezing method, time in storage, and packaging method on the amount of freezer burn occurring on hams[1]

Freezing method	Time in still-air storage	Packaging method			Total
		Glazed-polybagged	Unglazed-polybagged	Glazed	
	Months	*Sq. in*	*Sq. in*	*Sq. in*	*Sq. in*
Still-air	4	38.7	142.0	92.3	
	6	119.3	203.5	238.1	
Total		158.0	345.5	330.4	833.9
Forced-air	4	112.8	115.5	80.6	
	6	319.6	304.5	327.6	
Total		432.4	420.0	408.2	1,260.6
Blast freezer	4	115.2	134.3	19.7	
	6	171.7	146.4	196.7	
Total		286.9	280.7	216.4	784.0
Total		877.3	1,046.2	955.0	

[1] Each value, with the exception of totals, represents the total square inches of freezer burn on 16 sample hams on each pallet.

Table 8.–The effect of freezing method and time in storage on the amount of freezer burn sustained by hams

Time in still-air storage	Freezing method		
	Still-air	Forced-air	Blast freezer
Months	*Sq. in*	*Sq. in*	*Sq. in*
4	[1] 5.69a	6.44a	5.61a
6	11.69ab	19.83 b	10.72ab

[1] Means not followed by a common letter are significantly different ($P < 0.05$) in Duncan's Multiple Range Test.

Effect of Location on Pallet

Analysis of variance showed significant differences in amounts of freezer burn sustained by hams that had been stacked in different locations on the test pallets (appendix table 16). The more exposed the hams were to the refrigerated air surrounding the pallet, the faster they froze, and the more freezer burn they sustained. Hams stacked on the corner of the top layer, where they froze the fastest (location 4) and lost the least weight, sustained the greatest amount of freezer burn (tables 6 and 10); whereas, hams that had been stacked in the interior of the pallet, where they froze the slowest (location 1) and lost the most weight, incurred the least freezer burn (tables 6 and 10). This finding reinforced other recent research which demonstrated that meat that had been frozen rapidly and that had lost only a little weight developed more freezer burn than meat that had been frozen slowly

Table 9.–The effect of packaging method and time in storage on the amount of freezer burn sustained by hams

Time in still-air storage	Packaging method		
	Glazed-polybagged	Unglazed-polybagged	Glazed only
Months	*Sq. in*	*Sq. in*	*Sq. in*
4	[1] 5.56ab	8.16ab	4.01a
6	12.72ab	13.63ab	15.88 b

[1] Means not followed by a common letter are significantly different ($P < 0.05$) in Duncan's Multiple Range Test.

and that had lost an appreciable amount of weight.[7]

The method used to package hams did not substantially affect the amount of freezer burn that was forming on them anywhere except location 4. Here, the polybagged hams exhibited significantly more burn than those glazed and polybagged (table 10).

Relationship Between Total Weight Loss and Freezer Burn

Historically, the meat industry has accepted the development of freezer burn as being directly related to the amount of evaporative weight loss; that is, the greater the weight loss, the greater the formation of freezer burn on the meat surfaces. However, correlation analysis ($r = 0.05$) showed practically no relationship between the amount of freezer burn forming on the hams and the amount of total weight loss (fig. 11).

[7]Kaess, G., and Weidemann, J. F. Control of freezer burn. World Refrigeration, 14, p. 27. 1963.

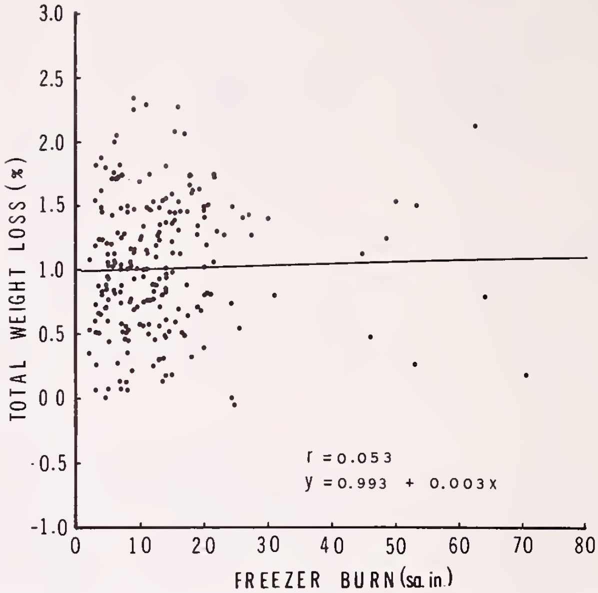

Figure 11.—Scatter diagram showing relationship between amount of freezer burn and percentage of total weight loss.

Table 10.–Effects of packaging method and location on pallet on the number of square inches of freezer burn per ham during frozen storage

Location on pallet[1]	Sides exposed	Packaging method[2]			Overall mean[3]
		Glazed-polybagged	Unglazed-polybagged	Glazed only	
	Number	*Sq. in*	*Sq. in*	*Sq. in*	*Sq. in*
1	0	5.20ab	4.41a	5.80ab	5.14
2	1	10.78 bc	10.37 bc	8.96abc	10.04
3	2	7.73abc	9.74abc	9.00abc	8.82
4	3	12.85 cd	19.07 e	16.03 de	15.98
Overall mean[4]		9.14	10.90	9.95	

[1] See figure 1 for illustration of ham positions on the pallet.

[2] Each mean represents the average number of square inches of freezer burn on 24 sample hams. Means not followed by a common letter are significantly different ($P < 0.05$) in Duncan's Multiple Range Test.

[3] Overall means were significantly different ($P < 0.01$) by analysis of variance.

[4] Overall means were not significant ($P < 0.05$).

RESULTS OF COST ANALYSIS OF SYSTEMS FOR HANDLING HAMS— PART 3 OF STUDY

Handling hams through a refrigerated warehouse can be costly to both warehouseman and customer alike. The customer wants the maximum protection at the lowest cost against weight loss and product deterioration. The warehouseman has essentially the same goals in order to maintain customer satisfaction, because he may be held accountable for excessive weight losses or deterioration of the meat while under his care.

Most refrigerated warehouses offer customers a variety of services for handling loose meat. The following tabulation shows the cost per hundredweight (cwt) for packaging and handling loose pork bellies and hams through a refrigerated warehouse. Figures used are an average of tariff quotations in the spring of 1970 from five Midwestern warehouses.

Item	*Cost/cwt*
Handling in and out of warehouse	$0.54
Spray glazing	.21
Pallet bagging (polybagging)	.29
Freezing (still- or forced-air)	.26
Blast freezing	.39
Storage (per month)	.25

Table 11 shows the weight losses of hams, the costs of these losses, and the warehousing services when hams were handled through the nine systems used in the experiments. Freezer burn loss was not included in this analysis, since no meat sustained enough freezer burn to necessitate trimming.

Of the nine handling systems analyzed, the system that costs the least ($2.32/cwt)[8] was a combination of freezing in a forced-air room, spray glazing, and storing on an open pallet. The most expensive ($2.70/cwt) was a combination of freezing in a forced-air room, spray glazing, and polybagging for storage.

The handling method selected partly depends on customer needs and on the basic services that are available in the warehouse where the meat will be stored. Some warehouses do not offer all the combinations of services shown in table 11, but the customer can use the information developed in this report to guide him in selecting a low-cost system applicable to his particular situation.

[8]The system costs in this analysis were based on the weight loss of hams in one experiment in one refrigerated warehouse. Weight loss may vary under conditions prevalent in other plants.

Table 11.—Weight losses of hams and costs of weight losses and warehousing services for hams by nine handling systems

Handling system	Weight loss/cwt [1]	Cost of weight loss/cwt [2]	Cost of warehousing services/cwt [3]	Total cost/cwt
	Pounds	*Dollars*	*Dollars*	*Dollars*
Still-air freezing:				
Polybagged, glazed	0.71	0.30	2.30	2.60
Polybagged, unglazed	.97	.41	2.09	2.50
Open pallet, glazed	1.09	.46	2.01	2.47
Forced-air freezing:				
Polybagged, glazed	.95	.40	2.30	2.70
Polybagged, unglazed	1.03	.43	2.09	2.52
Open pallet, glazed	.74	.31	2.01	2.32
Blast freeze:				
Polybagged, glazed	.55	.23	2.43	2.66
Polybagged, unglazed	.62	.26	2.22	2.48
Open pallet, glazed	.58	.24	2.14	2.38

[1] Based on average percentages for 2-, 4-, and 6-month storage periods, derived from table 5.
[2] Derived by multiplying column 1 by $0.42/lb, the price quoted for hams in the National Provisioner, March 17, 1971.
[3] Based on cost for services developed in tabulation on this page (includes 4 months' storage time).

CONCLUSIONS AND RECOMMENDATIONS

Increasing handling costs and more stringent meat inspection requirements are speeding changes in handling loose meat. The use of polybagging (enclosing pallet loads of loose meat in polyethylene bags) represents one example of changes being adopted by the industry to modernize and to gain greater marketing efficiency. The use of fiberboard bins for the palletized handling of loose meat represents another alternative.

In the past, much industry effort has been expended in preventing weight loss of loose meat during the storage phase of the warehousing cycle. However, in the experiment reported here, it was shown that the greatest weight loss occurs during initial freezing. Measures to prevent this loss should be directed toward this phase of the cycle.

Under the conditions of this study, blast freezing was the most effective freezing method for minimizing weight loss, because it provided the fastest freezing rate. However, the meat should not remain in a blast freezer for prolonged periods after the temperature in the center of the meat has reached the freezing point. Prolonged holding will cause excessive weight loss and freezer burn from the circulation of high-velocity air over the meat surfaces.

Polybagging did not reduce weight loss significantly in comparison with only glazing hams and storing them on an open pallet. However, polybagging did afford some protection against freezer burn on meat stored longer than 4 months. Various packaging films are available which could give better weight loss and freezer burn protection if they were applied before freezing. In addition, transit shrinkage and possible contamination could be reduced if the packaging film were applied to each piece of meat at the meat packinghouse. However, it is questionable whether the savings in weight loss and other types of deterioration would offset the cost of this type of packaging for loose meat. A feasibility study to determine this should be conducted.

Another promising alternative for reducing marketing costs is to handle loose meat in bulk fiberboard bins. Using bins offers the potential to greatly reduce the manual handling of meat, since it could be loaded on and off trucks and handled through the warehouse entirely with a forklift truck. A major problem is that meat will not freeze fast enough in the bins to prevent spoilage. Several methods could potentially increase the freezing rate of hams in these bins. One is to perforate the walls. Another is to inject a cryogenic refrigerant, such as carbon dioxide snow, into the load. Research should be conducted to develop feasible methods to freeze and handle loose meat in bulk fiberboard bins.

APPENDIX

Table 12.–Analysis of variance of weight loss during initial freezing

Source	Degrees of freedom	Mean square	Variance ratio (F)
Total	431		
Freezing method	2	6.94	[1] 23.93
Residual A[2]	8	.29	
Exposure on pallet	81	.10	[2] 1.67
Residual B[3]	324	.06	

[1] Significant at $P < 0.01$. [2] Pallet sample of 16 hams used as experimental unit. [3] Each sample ham used as experimental unit.

Table 13.–Analysis of variance of weight changes during glazing and storage

Source	Degrees of freedom	Mean square	Variance ratio (F)
Total	431		
Freezing method	2	0.14	0.39
Packaging method	2	3.02	[1] 8.39
Time in storage	2	2.73	[1] 7.58
Freezing method x packaging method	4	.09	.25
Freezing method x time in storage	4	.18	.50
Packaging method x time in storage	4	.21	.58
Freezing method x packaging method x time in storage (Residual A)[2]	8	.36	
Exposure on pallet/freezing method x packaging method x time in storage	81	.43	[3] 7.17
Residual B[4]	324	.06	

[1] Significant at $P < 0.05$. [2] Pallet sample of 16 hams used as experimental unit. [3] Significant at $P < 0.01$. [4] Each sample ham used as experimental unit.

Table 14.–Analysis of variance of weight changes during thawing

Source	Degrees of freedom	Mean square	Variance ratio (F)
Total	431		
Freezing method	2	0.39	0.59
Packaging method	2	1.20	1.82
Time in storage	2	29.56	[1] 44.79
Freezing method x packaging method	4	.33	.50
Freezing method x time in storage	4	.18	.27
Packaging method x time in storage	4	.98	1.49
Freezing method x packaging method x time in storage (Residual A)[2]	8	.66	
Exposure on pallet/freezing method x packaging method x time in storage	81	.13	[3] 1.44
Residual B[4]	324	.09	

[1] Significant at $P < 0.01$. [2] Pallet sample of 16 hams used as experimental unit. [3] Significant at $P < 0.05$. [4] Each sample ham used as experimental unit.

GPO 862-671

Table 15.–Analysis of variance of total weight loss

Source	Degrees of freedom	Mean square	Variance ratio (F)
Total	431		
Freezing method	2	5.15	[1] 7.57
Packaging method	2	.72	1.06
Time in storage	2	14.75	[2] 21.69
Freezing method x packaging method	4	1.19	1.75
Freezing method x time in storage	4	.85	1.25
Packaging method x time in storage	4	1.32	1.94
Freezing method x packaging method x time in storage (Residual A)[3]	8	.68	
Exposure on pallet/freezing method x packaging method x time in storage	81	.59	[2] 4.92
Residual B[4]	324	.12	

[1] Significant at $P < 0.05$. [2] Significant at $P < 0.01$. [3] Pallet sample of 16 hams used as experimental unit. [4] Each sample ham used as experimental unit.

Table 16.–Analysis of variance of square inches of freezer burn

Source	Degrees of freedom	Mean square	Variance ratio (F)
Total	287		
Freezing method	2	714.77	[1] 27.37
Packaging method	2	74.44	2.85
Time in storage	1	4,804.45	[1] 183.94
Freezing method x packaging method	4	158.42	6.07
Freezing method x time in storage	2	495.67	[1] 18.98
Packaging method x time in storage	2	263.91	[2] 10.10
Freezing method x packaging method x time in storage (Residual A)[3]	4	26.12	
Exposure on pallet/freezing method x packaging method x time in storage	54	168.90	[1] 2.25
Residual B[4]	216	74.98	

[1] Significant at $P < 0.01$. [2] Significant at $P < 0.05$. [3] Pallet sample of 16 hams used as experimental unit. [4] Each sample ham used as experimental unit.